

APPLICATION OF REMOTE SENSING TECHNIQUES FOR PREDICTION OF LANDSLIDE HAZARD AREAS IN MALAYSIA

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Abstract

Landslides hazard occurs mostly due to instability of terrain surface and directly related to several parameters such as surface temperature, land use type, terrain slope and underground water level. Remote sensing techniques have been widely used to study characteristics of land surface due to the advantage of repetitive data acquisition over wide areas in a short time. Spatial analysis using data derived from remote sensing techniques and other thematic map data may facilitate greatly prediction and estimation of landslide hazard areas.

In this paper, landslide hazard studies carried out in the Genting Sempah area of Malaysia is presented. Landsat-TM satellite data have been used to derive land surface temperature and land use information. The elevation and terrain slope have been determined from Digital Elevation Model (DEM) generated from aerial photographs using stereo correlation techniques. Underground water level information has been estimated from the combination of the above data. From these data, simple algorithms were used to classify the area into different risk zones. By combining all the risk maps using spatial analysis techniques, a final risk map was produced which take into account all the above factors.

1.0 Introduction

Landslides have become one of the major natural disasters in many countries. Prediction of potential natural landslide areas have been very difficult because of the complexity of the factors involved and the relationship to each other which is wide ranging. The factors which are usually related to landslides are geology, soil type, land surface temperature, land use, underground water level, slope and elevation. Normally the causes of landslides are determined by carrying out some sampling of the soil, rock, slope inclination, land use, underground water level and geology at the site. This is difficult and time consuming for large areas. With remote sensing techniques one can obtain information for a large area from time to time and by integrating it with GIS, all information can be combined, manipulated and analysed to determine potential landslide areas. The objective of this study is to determine a suitable methodology of predicting possible landslide areas using remote sensing satellite images.

2.0 Study Area

The study area covers an area of about 8 x 10 sq. km and is located at Genting Sempah, an area which cuts across a mountainous area connecting the west and the east coast region of Peninsular Malaysia (Figure 1). This area is dominantly covered by primary forest and vegetated areas. Some small villages and agricultural sites are found in the area.

Paper presented at the 14th United Nations/International Astronomical Federation Workshop on “*Capacity Building in Space Technology for the Benefit of Developing Countries*” with an Emphasis on Natural Disaster Management, 2 – 3 October 2004, Vancouver, Canada.

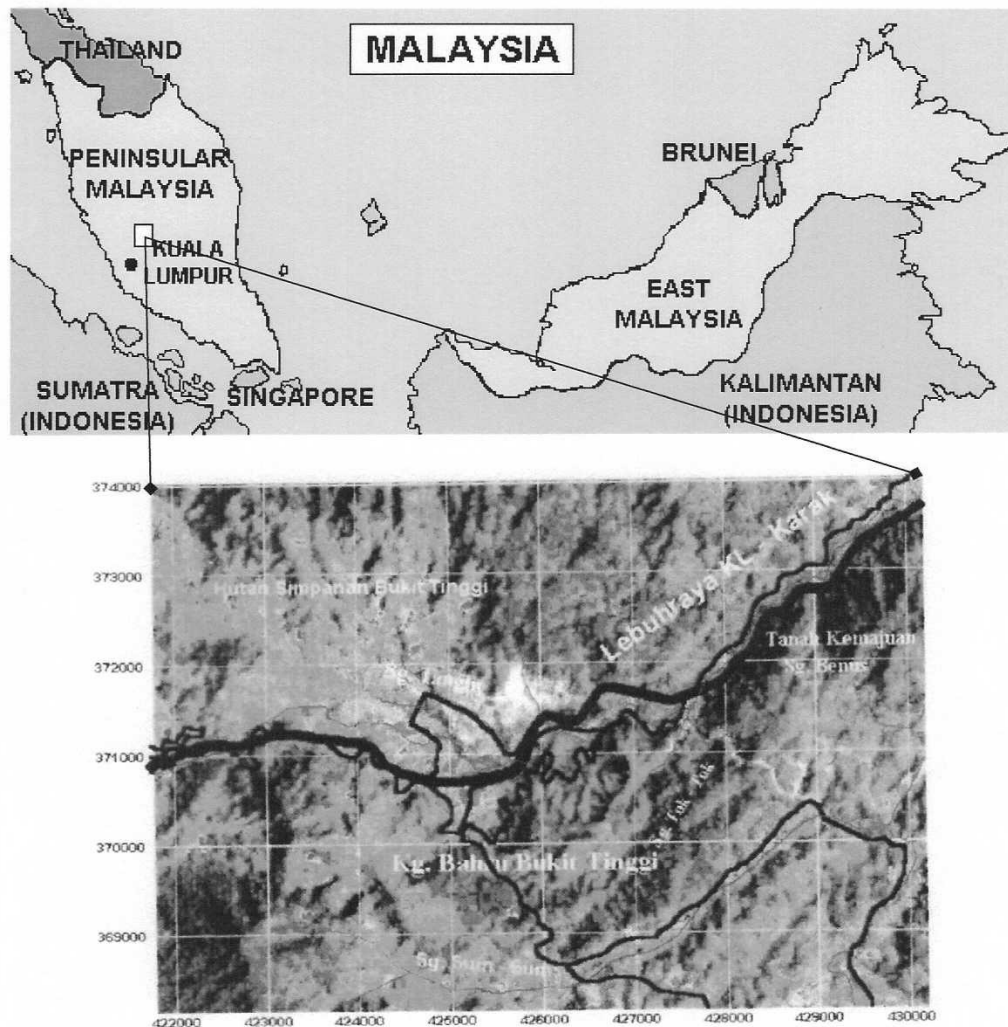


Figure 1 : Location of the study area (above) and geometrically corrected Landsat-TM image(below) used in the study.

3.0 Data Processing and Information Extraction

In the study, various types of data were used to extract relevant information. These include the use of Landsat-5 TM data in the extraction of land surface temperature, land use information and underground water level and aerial photographs in the deriving of DEM.

The information derived from remote sensing techniques includes :

- a) Land surface temperature,
- b) Elevation risk,
- c) Slope risk,
- d) Land use, and
- e) Underground water level.

The geology of the area was not considered since the whole area is covered by one type of geology, i.e. granite.

3.1 Land Surface Temperature

The land surface temperature which is closely related to underground water level is usually used by researchers to predict landslide potential areas. The Landsat-5 TM band 6 (10.4 – 12.5 μm) data was corrected for atmospheric effects and the land surface temperature was calculated based on Planck's Law given in equation (1) below.

$$T_R = \frac{K_2}{\ln\left(\frac{K_1}{L_c} + 1\right)} \quad \dots\dots\dots (1)$$

where T_R = land surface temperature ($^{\circ}\text{K}$),
 K_1 = calibration constant (60.776 $\text{mWcm}^{-2}\text{sr}^{-1}\mu\text{m}^{-1}$),
 K_2 = calibration constant (1260.56 K), and
 L_c = corrected radiance for each pixel.

The radiance, L_c received by the sensor is as below.

$$L_c = \left\{ \frac{(L_u - L_a)}{\varepsilon\tau} - \left(\frac{1}{\varepsilon} - 1 \right) \right\} L_{\text{sky}} \quad \dots\dots\dots (2)$$

where

L_c = corrected radiance,
 L_u = uncorrected radiance,
 L_a = path radiance or radiance from atmosphere,
 $L_{\text{sky}} = f \sigma T_A^4 \{1 - 0.26 \exp\{-7.77 \times 10^{-4} (273 - T_A)^2\}\}$,
 ε = emissivity,
 τ = transmittance of atmosphere,
 T_A = absolute air temperature at land surface,
 σ = Stefan-Boltzman constant ($5.67 \times 10^{-8} \text{Wm}^{-2}\text{K}^{-4}$), and
 f = part of heat radiation at 10.44 and 12.42 μm wavelength (=0.3187).

The result is shown in figure 2 where the temperature ranges from 24°C to 34°C. According to previous research works (Shikada et al., 1994), most landslide areas have temperature between 24°C to 26°C.

3.2 Elevation Risk

In order to derive elevation risk map, Digital Elevation Model (DEM) for this study was generated from a pair of aerial photographs (figure 3). The elevation ranges from 0 to 850 m in this area. The potential landslide risk map based on elevation was generated using the algorithm of Gao & Lo (1995) as follows :

$$P_1 = (1.2823H^2 - 0.001847H^3) / 10^6 \quad \dots\dots\dots (3)$$

where

H = elevation (in meters), and
 P_1 = potential landslide (in %)

The elevation risk map was classified into four ranges, i.e. 0 – 2%, 3 – 5%, 6 – 8% and 9 – 12% (figure 4).

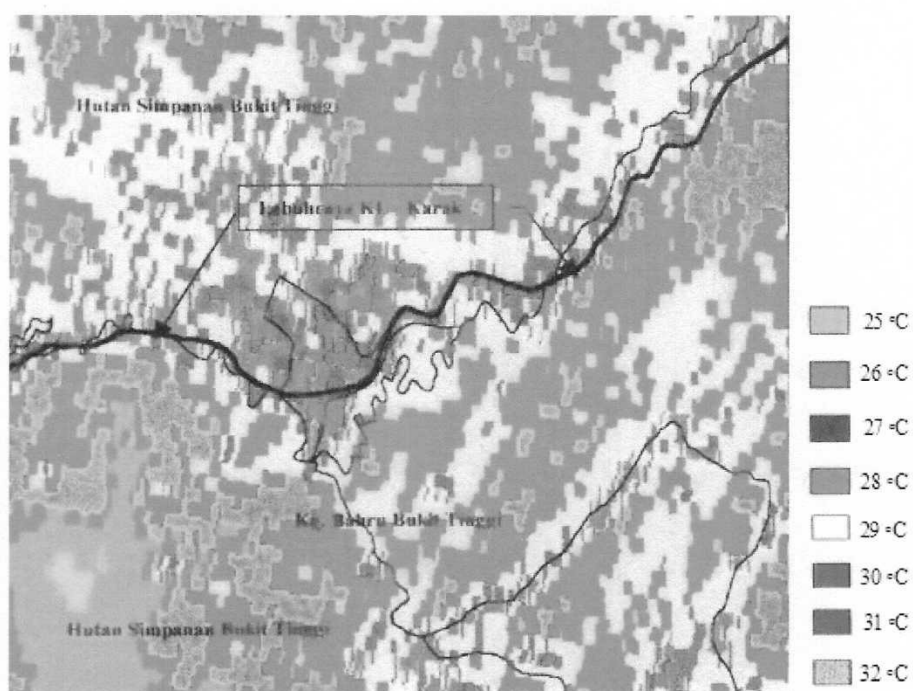


Figure 2 : Land surface temperatures.

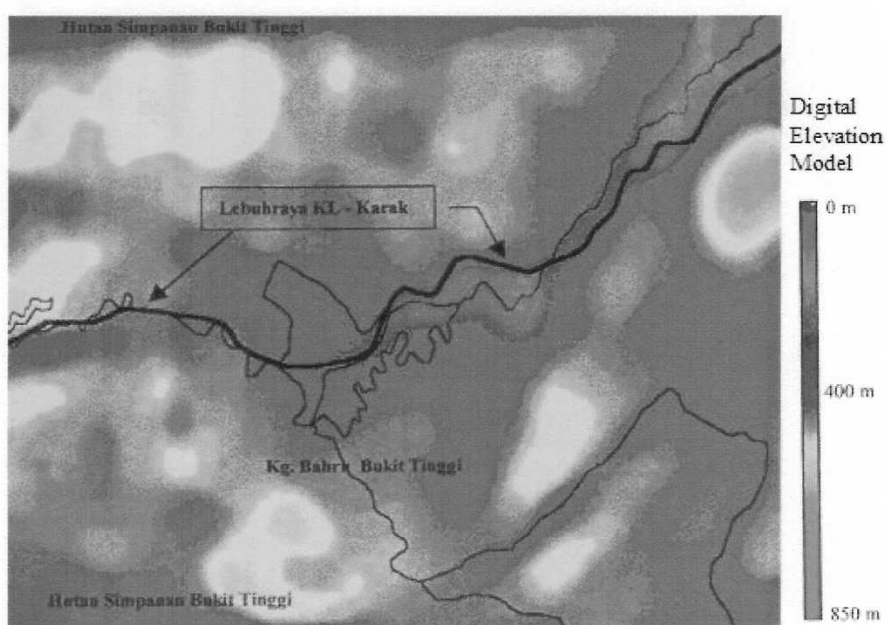


Figure 3 : DEM of the study area.

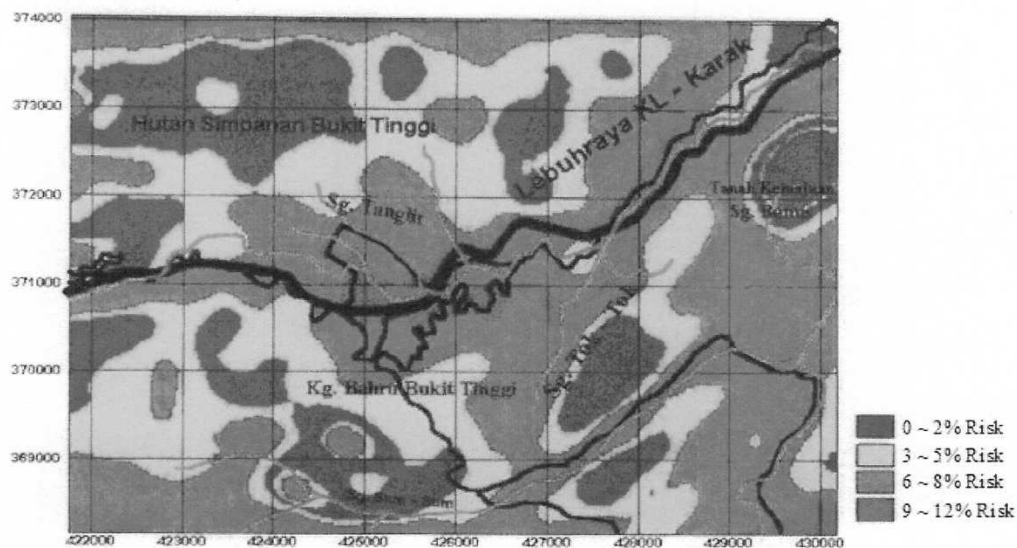


Figure 4 : Elevation risk map.

3.3 Slope Risk

The slope risk map was also generated from the DEM. The slopes in this area range from $0 - 60^\circ$. The potential landslide risk map based on slope was generated by using the algorithm of Gao & Lo (1995) as follows :

$$P(\theta) = \exp (1829.49 \theta - 55.16 \theta^2 + 0.65469 \theta^3) / 1000 \quad \dots\dots\dots (4)$$

where θ = gradient, and
 $P(\theta)$ = potential landslide (in %).

The result was density sliced at 5% interval, i.e. 0-5, 6-10, 11-15, 16-20, 21-25 and >25% risk (figure 5).

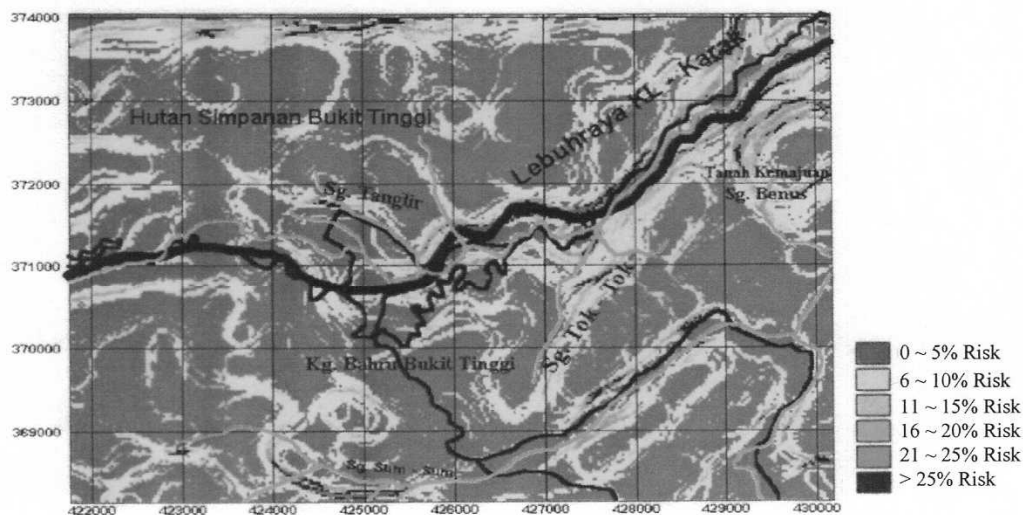


Figure 5 : Slope risk map.

3.4 Land Use

A land use map was produced from the satellite Landsat-5 TM data. The land use for the study area is classified into 4 types, i.e. forest, bush, agriculture and residential by using the nearest neighbour method of supervised classification technique. The land use map as shown in figure 6 is then density sliced into different risk zones according to results from previous research works. According to Morgan (1986), agriculture areas undergo more soil erosion followed by bush, forest and residential.

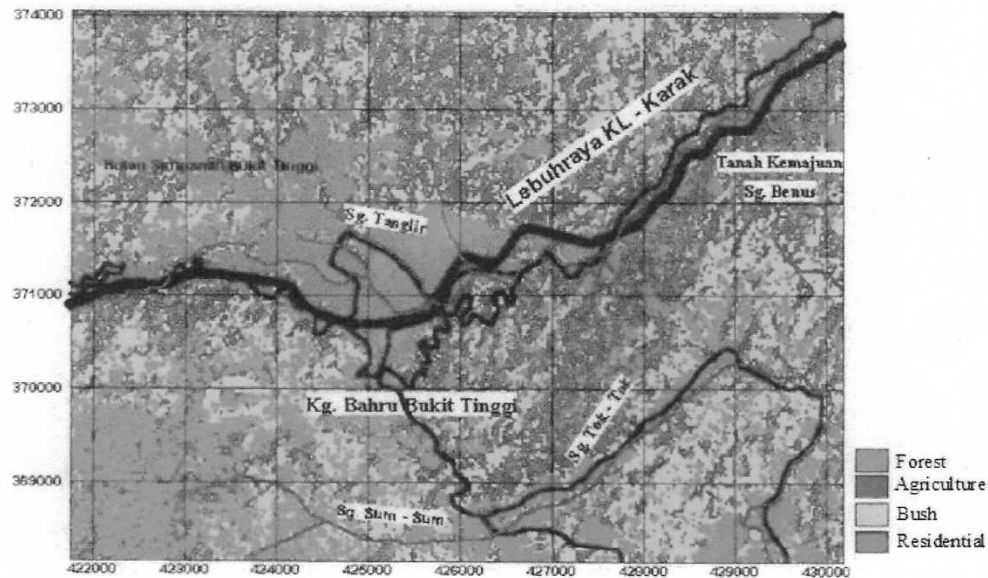


Figure 6 : Land use map.

3.5 Underground Water Level

The occurrence of landslides is also related to underground water level. The underground water level map was produced from the combination of the above data which include the slope, elevation, spectral radiance of band 6 of Landsat-5 TM data and Normalised Difference Vegetation Index (NDVI). The underground water level is derived as described below.

$$UWL = \frac{(B_6 \times NDVI \times EL)}{\sqrt{SL}} \quad \dots\dots\dots (5)$$

where

- UWL = underground water level,
- B_6 = band 6 spectral radiance,
- NDVI = Normalised Difference Vegetation Index,
- EL = elevation (meter), and
- SL = slope (in degrees).

The underground water level map was density sliced at 3 m interval. The result is as shown in figure 7 with the underground water level ranging from 0 – 18 m. Wet and agriculture areas have shallow water levels. According to previous research works, most of the landslides occur at underground water level of 3 - 6 m (Takagi and Murai, 1991).

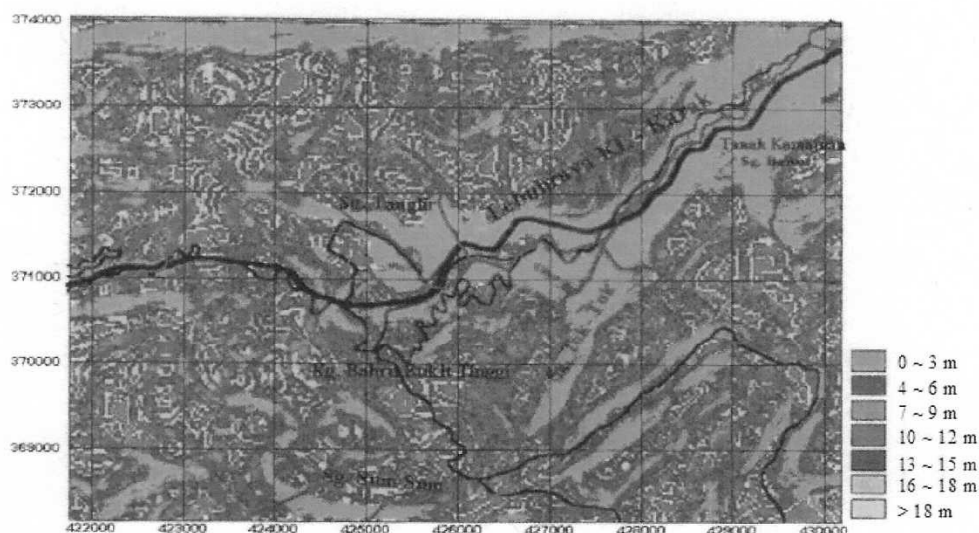


Figure 7 : Underground water level map.

4.0 Determination of Final Landslide Risk Map

All the above data were processed by using GIS software. All the landslide risk maps that were generated above were combined to produce the final risk map (figures 8 & 9).

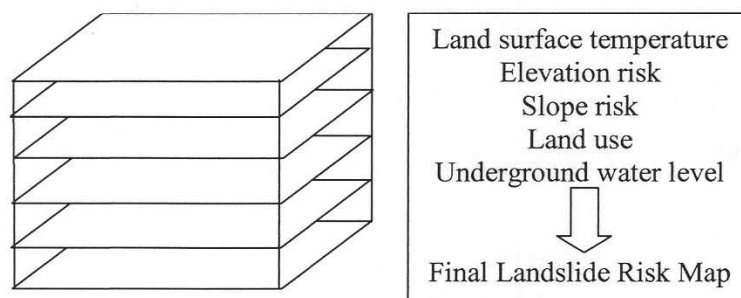


Figure 8 : Overlay of all landslide risk maps to produce Final Landslide Risk Map.

Figure 7 shows that most of the risk areas are located in areas along the road side and at agriculture areas. These areas have temperatures between $24 - 26^{\circ}\text{C}$, slopes between $35^{\circ} - 45^{\circ}$, elevation between $400 - 500$ m and underground water level between $3 - 6$ m. Although there is no evidence to prove that these areas are risky, the combination of the above factors indicates that these areas are more risky than other areas in the study area.

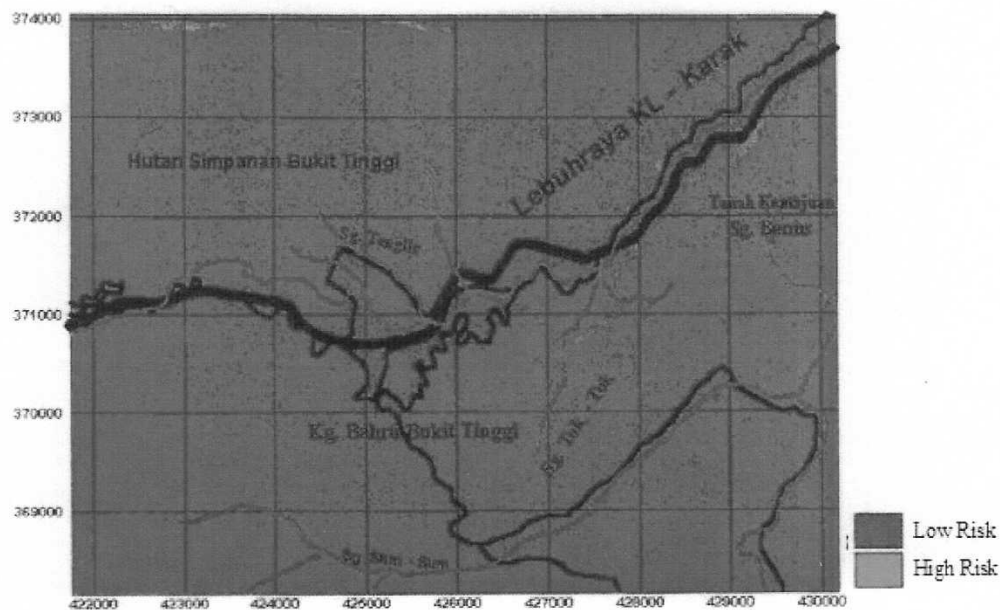


Figure 9 : Landslide risk map combination of all factors.

5.0 Conclusion

The study shows that remote sensing techniques when integrated with GIS can provide a useful tool to study potential landslide areas. However, the accuracy of the final result depends on the parameters that are included in the data set. In this study, not all the necessary parameters have been included due to lack of data.

Acknowledgement

The authors wish to thank Richard Kho Shu Yuan for his contributions in the study.

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